THE RADIO-ACTIVE POINT OF VIEW.

By WILLIAM DUANE.

In estimating the age of the earth one should measure the time that has elapsed by some process in nature that takes place in one direction only and that does not change its rate when conditions (temperature, pressure, etc.,) alter. In most of the estimates of geological periods of time that have been made, the "clocks" employed do not fulfill these conditions. Estimates based on the temperature of the earth, or of the sun, for instance, cannot be reliable, for the temperature of a body may fall or it may rise. Further, the rate of change of the temperature depends upon a variety of conditions, such as the amount of energy radiated, the supply of energy to it, etc.

Attempts have been made to deduce the age of certain minerals from the appearance of little round marks in them, called haloes. These haloes are supposed to be due to radiation from minute specks of radio-active matter at their centers. The colors produced by radiation in transparent substances depend, to a considerable extent, upon the temperature, so that no very great weight can be put upon geological periods of time estimated by means of haloes.

There are, however, other radio-active processes, the rates of which do not, so far as we know, depend on the temperature or the pressure, nor upon any other physical or chemical state.

During the last twenty-five years a large number of radio-active transformations of one chemical element into another have been discovered. Students of the subject agree that these transformations take place in one direction only, *i.e.*, from an element of higher atomic weight to an element of lower atomic weight. Further, nobody has been able to alter the rate of a radio-active transformation by any process whatsoever, although numerous attempts have been made to do so. These radio-active changes, therefore, seem to offer a reliable means of estimating certain periods of time.

Among the radio-active changes appear processes in which the metal uranium transforms itself through successions of intermediate stages into the metal lead and into the gas helium. It does not seem necessary to describe in detail these series of transformations at this time. Descriptions of them may be found in the literature on radio-activity. It suffices for our purposes to say that the rate of transformation is such that 5 per cent. of a quantity of uranium changes into lead and helium in about 370 millions of years.

We find uranium, lead and helium associated together in a great many minerals and it is natural to suppose that the helium and the lead were produced by the disintegration of the uranium during the past ages. Further, if we determine the relative amounts of uranium, lead and helium in a mineral we can form an estimate as to how long these chemical elements have been in contact with each other. Estimates of this kind that have been made from the quantities of helium in uranium ores vary between 8 and 700 millions of years, according to the locality from which the ore came. Since some of the helium (it being a gas) may have leaked out of the ores these intervals of time must be regarded as minimum estimates. The uranium and helium must have been in contact with each other for at least as long as the periods mentioned, but they may have been together for much longer intervals of time.

Calculations based on the quantity of lead in uranium ores vary from 340 millions to 1,700 millions of years, according to the locality from which the ore is obtained. In this case another complication appears. We have learned to distinguish several different kinds of lead from each other. The various kinds of lead have similar chemical properties but differ from each other in their atomic weights. All the different kinds of lead do not come from uranium; only lead of atomic weight about 206 may be regarded as produced from uranium. Until, therefore, we have determined exactly what the atomic weights of the lead in the various ores really are, we cannot be sure that the lead came from the uranium. We can assert, however, that there is no more uranium lead in a given uranium ore than the amount of lead actually found. Unless, therefore, the atomic weight of the lead in an ore has been actually determined and found to be about 206, we must consider the estimate of the age of the ore as a maxi-

mum estimate only. The lead and uranium cannot have been in contact with each other for a period of time longer than that calculated from the known rate of transformation of uranium into lead.

The atomic weight of the lead in a few ores has been found to be very close to 206. In one of these the age of the mineral has been estimated at a little over 900 millions of years.

The calculation of the age of uranium deposits by means of radio-active data rests upon the laws of nature as we now believe them to be. It would be a waste of time to speculate on future discoveries (new radio-active elements, for instance, or alterations in the rates of radio-active processes) or on a possible evolution of natural law.

The ages calculated from radio-active data represent the length of time during which we may suppose the chemical elements to have been in more or less mechanical contact with each other. They do not represent the time that has elapsed since the earth may have reached a state capable of supporting organic life as we now know it.

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